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The mites (Acari) of an old Scots pine forest polluted by a nitrogen fertilizer factory at Włocławek (Poland). II.: litter/soil fauna

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Abstract

The soil mite communities of areas totally covered with dead needles, in an old Scots pine forest (plant association *Leucobryo-Pinetum*) polluted by a nitrogen fertilizer factory at Włocławek, were investigated. Small concentrations of air pollution stimulated the abundance of mites and increased the species diversity of Oribatida, but decreased the species diversity of Gamasida. A high concentration of these pollutants was harmful to mites. A seasonal fluctuation in density of mites was observed in polluted soils; it was probably caused by a great mortality of mites in winter, and the stimulating influence of some pollutants on mite density during the growing season. Some species of Oribatida and Gamasida were sensitive to air pollutants, and some tolerated them.

1. Introduction

In a previous paper (SENICZAK & DĄBROWSKI 1993) the arboreal mites and epiphytes, polluted by a nitrogen fertilizer factory at Włocławek, were presented. Air pollution from this factory stimulated algal growth, and in small concentrations also lichen growth; a high concentration of pollution was harmful to lichens. The density of mites and the species diversity of Oribatida and Gamasida decreased in the plots approaching the pollution source.

In this paper the effects of pollution on the soil mites of this Scots pine forest (plant association *Leucobryo-Pinetum*), approximately 80 years old, are considered. In this forest Scots pine (*Pinus sylvestris* L.) predominates, with small participation of birch (*Betula pendula* Roth), oak (*Quercus robur* L.) and spruce (*Picea abies* (L.) Kersten). In a control plot, the brushwood is represented mainly by juniper (*Juniperus communis* L.), whereas in polluted plots, bird cherry (*Prunus serotina* Ehrh.) predominates. The soil in this forest is either covered with mosses and herbs

or only dead needles; in polluted plots mosses and herbs are mixed with grasses.

The chosen plots were situated at distances of 1.2 km (plot 1), 2.5 km (plot 2) and 5 km (plot 3) from the pollution source, and a control plot was situated 25 km from this source. Only those areas totally covered with dead needles were chosen. The location of these plots and the description of study areas, including the concentration of some pollutants in epiphytes, were given earlier (SENICZAK & DĄBROWSKI 1993).

2. Methods

Samples were taken during four periods: in spring and autumn of 1986 and 1987. Ten samples of 17 $cm^2 \times 21.5$ cm in volume were taken from each plot in the four sampling periods in one series, and these were further divided into 5 vertical soil horizons: AoL, AoF, AoFH, A1A2 and Br. The thicknesses of these horizons were approximately 3 cm, 2.5 cm, 1 cm, 9 cm and 6 cm. Mites were extracted from the material in modified Tullgren funnels. Over 3.18×10^4 mites were extracted in total, including 2.23×10^4 Oribatida and 2.4×10^3 Gamasida.

We determined all individuals of Oribatida and Gamasida to species or genus. The exception was the family Brachychthoniidae whose juvenile stages could not be identified with certainty. Other mites were identified to order. For the analysis of species' occurrence in samples we used abundance (*A*), dominance (*D*) and constancy (*C*) indices (ODUM 1982).

The pollution level in soil horizons was determined in pooled material collected from each of investigated horizons. We determined the content of ammonium and nitrate ions by colorimetric analysis, and the sulphur content by a photometric method.

Differences between mean abundances of mites in the polluted and control plots were tested for significance using the *d* test for $n > 30$ (PARKER 1978). The values that are significantly different from the control are marked with (*), (**) and (***), according to the level of confidence $p = 0.05$, $p = 0.01$ and $p = 0.001$, respectively.

3. Results

3.1. Density of mites

The density of mites in the control plot was comparable with other similar forests in Poland (RAJSKI 1961, SENICZAK 1978). In polluted plot 1, situated nearest to the pollution source, the density of mites was distinctly lower, and in polluted plot 2, situated further from this source, it was slightly lower than in plot 3 and the control (Tab. 1). In polluted plot 1 all groups of mites, except Gamasida, occurred in relatively small numbers, and they achieved the highest density in plot 3 or in the control.

Table 1

The density of mites (mean value in thousand · $1m^{-2}$) in soil areas covered with dead needles, in Scots pine forest polluted by the nitrogen fertilizer factory at Włocławek.

Group of mites	Plot 1	Plot 2	Plot 3	Control
Oribatida	44,90	79,40	93,85	81,20
Actinedida	12,25	22,40	31,10	29,50
Gamasida	6,95	8,00	7,45	8,95
Others	1,90	3,90	4,70	8,75
Acari	66,00	113,70	137,10	131,60

Among soil mites the Oribatida predominated, with Actinedida second in abundance. These two groups presented a similar pattern of abundance. They were most abundant in plot 3, situated further from the pollution source, and had low densities in plot 1, situated nearest to the pollution source. In plot 1, the density of Gamasida was only slightly lower, and in other polluted plots it was similar to the control. The differences in density of total Acari, Oribatida and Actinedida between polluted plot 1 and the control were statistically significant (Tab. 2).

In the control plot the abundance of mites was similar in both seasons, but the density of mites in polluted plots fluctuated greatly between spring and autumn (Tab. 3). The pattern observed in our sampling suggests a distinct reduction of density in the spring in these plots, mainly in plots 1 and 2, situated nearer to the pollution source, probably by nitrogen pollutants.

The reduction of mite density in polluted plot 1 was in an agreement with a high pollution content in the soil. Based on the soil analysis (Tab. 4), nitrogen ions accumulated mainly in this plot, with distinctly lower concentrations in other plots. In plot 1 the amount of ammonia cations and nitrate anions in AoL and AoFH horizons was about 3 times higher than in the control. Consequently in the former plot, the C/N coefficient was lower than in the latter plot.

In the autumn, the abundance of mites in polluted plots rapidly increased. In plots 1 and 2, situated nearer to the pollution source, the abundance was about 2 times higher, and in the plot 3, situated further from this source, it was about 1.5 times higher than in the spring (Tab. 3). In polluted plots 2 and 3 the mites achieved even higher densities than in the control plot, which was probably caused by the stimulating influence

Table 2

The *d* value calculated between the mean mite density in soil areas covered with dead needles, in Scots pine forest polluted by the nitrogen fertilizer factory at Włocławek.

Taxa	Plots		
	1-Control	2-Control	3-Control
Acari	5,93***	1,45	0,23
Oribatida	5,44***	0,35	2,29*
Actinedida	3,91***	1,57	0,11
Gamasida	1,24	0,75	0,31
Brachychthoniidae	3,85***	2,87**	0,48
Eremaeus oblongus	4,15***	3,84***	5,07***
Licneremaeus licnophorus	4,66***	1,16	9,77***
Oppiella nova	4,17***	3,82***	2,57*
Oribatula tibialis	7,95***	1,38	1,11
Quadroppia quadricarinata	5,73***	6,37***	14,58***
Suctobelba sp.	1,89	7,69***	7,92***
Tectocepheus velatus	15,97***	1,53	0,73
Zercon triangularis	4,11***	6,27***	5,01***

n = 40 * – p = 0,05 ** – p = 0,01 *** – p = 0,001

of small concentrations of air pollution on the development of soil mites during the growing season.

3.2. Vertical distribution of mites

The mites occupied mainly the organic layer, especially the litter (AoL) or fermentation (AoF) horizons (Tab. 5): the mineral soil (A1A2 and Br) was inhabited by few mites.

In the control plot and plot 3, situated further from the pollution source, the mites were relatively abundant in horizons AoL and AoF, whereas in polluted plots 1 and 2, situated nearer to this source, they concentrated in the horizon AoF. The movement of mites, mainly Oribatida and Actinedida which predominated, out of the uppermost horizon AoL in plots 1 and 2 was probably caused by the air pollution. The Gamasida were abundant in the horizon AoF in all polluted plots, but in the control they concentrated in horizon AoL.

Table 3: The density of mites (mean value in thousand · $1m^{-2}$) in spring and autumn in soil areas covered with dead needles, in Scots pine forest polluted by the nitrogen fertilizer factory at Włocławek.

Taxa	Plot 1		Plot 2		Plot 3		Control	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
Acari	43,3	88,7	71,9	155,5	107,2	167,0	130,1	133,1
Oribatida	31,2	58,6	44,7	114,1	79,9	107,8	79,8	82,6
Actinedida	6,9	17,6	15,0	29,8	19,6	42,6	27,0	32,0
Gamasida	3,2	10,7	7,5	8,5	4,3	10,6	7,3	10,6
Eremaeus oblongus	1,0	3,4	3,9	17,7	1,1	3,3	6,6	5,0
Oppiella nova	0,1	0,3	0,1	0,5	0,3	1,3	0,4	3,1
Oribatula tibialis	0,2	0,1	2,8	3,2	1,9	1,7	3,8	3,9
Quadroppia quadricarinata	2,4	2,2	1,2	4,1	4,4	7,4	0,5	0,2
Tectocepheus velatus	4,8	28,0	18,3	37,8	31,6	31,1	29,8	36,9
Zercon triangularis	0,2	1,4	0,1	0,1	–	0,2	0,8	4,0

Table 4: Some physical and chemical properties of forest soils, in Scots pine forest polluted by the nitrogen fertilizer factory at Włocławek, after MALCZYK (1988).

Plot	Horizon	Moisture % by weight	pH in 1n KCl	Humus content %	C/N	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	Cl^-	$S\text{-}SO_4^{-2}$
						mg in 100 g of soil			
1	AoL	145,5	4,1	81,9	28,1	61,0	196,1	31,8	25,5
	AoF	76,9	3,2	48,7	18,8	15,5	85,4	47,3	10,8
	AoFH	61,8	2,8	35,1	17,5	64,8	284,7	18,4	14,0
	A1A2	4,9	3,6	1,9	14,9	0,9	1,7	2,4	1,8
	Br	4,2	3,9	0,6	11,1	0,1	0,7	2,1	3,1
2	AoL	95,7	3,5	77,6	30,8	16,4	76,4	119,6	35,9
	AoF	80,6	3,2	56,3	24,3	18,9	62,6	25,0	11,7
	AoFH	80,1	2,9	36,9	21,3	8,8	111,2	15,6	8,9
	A1A2	5,8	4,4	1,7	30,2	0,1	0,3	16,1	4,0
	Br	3,2	5,0	0,6	24,7	0,1	0,2	3,6	3,4
3	AoL	115,2	3,4	82,6	31,0	18,1	89,9	47,6	22,4
	AoF	93,6	3,1	55,7	27,2	23,4	62,3	15,2	8,5
	AoFH	45,9	2,7	34,4	17,8	10,2	48,8	12,7	5,5
	A1A2	5,5	4,0	1,7	33,2	0,1	0,5	3,5	1,6
	Br	3,6	4,5	0,5	24,6	0,1	0,4	2,3	2,6
C	AoL	157,6	3,5	78,6	36,6	20,2	82,0	48,5	30,2
	AoF	89,2	3,3	63,7	30,2	23,8	75,8	20,3	10,5
	AoFH	144,1	2,6	44,5	28,4	14,8	73,2	13,5	6,1
	A1A2	7,7	3,8	1,4	22,4	0,2	0,4	2,7	2,0
	Br	5,1	4,0	0,6	24,4	0,1	0,4	1,8	3,5

Table 5

Vertical distribution of mites in soil areas covered with dead needles, in Scots pine forest polluted by the nitrogen fertilizer factory at Włocławek. Mean density of mites per 100 cm^3 volume is given.

Group of mites	Horizon	Plot 1	Plot 2	Plot 3	Control
Oribatida	AoL	48,3	111,3	159,4	116,4
	AoF	101,7	167,4	163,6	151,0
	AoFH	28,2	40,3	33,0	50,7
	A1A2	2,2	5,9	3,7	3,3
	Br	0,2	0,5	0,4	0,1
Actinedida	AoL	11,7	30,2	76,5	63,4
	AoF	26,2	42,6	17,2	54,4
	AoFH	11,0	10,8	7,4	12,1
	A1A2	2,6	2,9	0,8	0,4
	Br	0,2	0,2	0,1	0,3
Gamasida	AoL	9,4	7,1	8,1	16,3
	AoF	12,5	17,6	11,3	12,0
	AoFH	2,2	4,1	4,2	2,4
	A1A2	0,6	0,7	0,2	0,5
	Br	0,1	0,5	0,3	0,1
Others	AoL	1,5	4,5	3,2	7,2
	AoF	4,0	7,0	13,1	15,5
	AoFH	2,9	2,7	1,8	2,9
	A1A2	0,2	1,1	0,2	0,1
	Br	–	0,1	–	–
Total Acari	AoL	70,9	153,1	247,2	203,3
	AoF	144,4	234,6	205,2	232,9
	AoFH	44,3	57,9	46,4	68,1
	A1A2	5,6	10,6	4,9	4,3
	Br	0,5	1,3	0,8	0,5

3.3. Species diversity of Oribatida

From the investigated plots, 61 taxa of oribatid mites were recorded (Tab. 6). Most of them inhabited the polluted plot 2, and the fewest occurred in most polluted plot 1. The relatively small number of taxa in polluted plot 1 probably indicates soil degradation under the influence of high concentration of pollution, whereas the large number of species in polluted plot 2 indicates soil eutrophication.

Nearly half of all species were found in all investigated plots. Six species occurred exclusively in the control plot, and no species occurred exclusively in most polluted plot 1.

Table 6

Taxa of Oribatida in soil areas covered with dead needles, in Scots pine forest polluted by the nitrogen fertilizer factory at Włocławek.

Name of taxon	Plot 1	Plot 2	Plot 3	Control
Achipteria coleoptrata (L.)		+		
Adoristes ovatus (C. L. Koch)	*	*	+	*
Brachychthoniidae	o	*	*	*
Camisia biurus (C. L. Koch)		+	+	+
C. segnis (Hermann)	+	+	+	+
C. spinifer (C. L. Koch)	+	+	+	+
Carabodes coriaceus (C. L. Koch)				+
C. forsslundi Sellnick		+	+	+
C. labyrinthicus (Michael)	+	+	+	+
C. marginatus (Michael)				+
C. minusculus Berlese				+
C. subarcticus Trägårdh	+	+	+	+
Ceratoppia quadridentata (Haller)	+	+		
Ceratozetes thienemanni Willmann				+
Chamobates schuetzi (Oudemans) x/	+	+	+	+
Cymbaeremaeus cymba (Nicolet)		+		
Damaeus sp.	+		+	+
Damaeobelba sp.			+	
Eporibatula rauschenensis (Sellnick)		+	+	
Eremaeus oblongus C. L. Koch	*	⊛	*	o
Eulohmannia ribagai Berlese	+	+	+	+
Eupelops torulosus (C. L. Koch)	+	+	+	+
Galumna lanceata Oudemans	+	+	+	+
Galumna 1		+	+	+
Gymnodamaeus bicostatus C. L. Koch		+		
Hemileius initialis (Berlese)	+	+	+	+
Heminothrus peltifer (C. L. Koch)		+	+	
Hypochthonius rufulus C. L. Koch			+	
Liacarus coracinus (C. L. Koch)		+		+
Licneremaeus licnophorus (Michael)	+	*	⊛	*
Metabelba pulverosa Strenzke	*	*	*	*
Micreremus brevipes (Michael)	+	+	+	+
Microtritia minima (Berlese)	+	+	+	*
Multioppia glabra Mihelčič		+		+
Nanhermannia nanus (Nicolet)		+		
Nothrus silvestris Nicolet	+	+	+	*
Oppiella minus (Paoli)	+	+	+	*

Name of taxon	Plot 1	Plot 2	Plot 3	Control
O. neerlandica Oudemans	+	*	*	+
O. nova (Oudemans)	+	+	+	*
O. subpectinata (Oudemans)		+		+
O. translamellata (Willmann)		+		
Oribatella calcarata (C. L. Koch)		+		
Oribatula tibialis Nicolet	+	*	*	*
Oribatula 1		+		
Parachipteria willmanni Hammen		+		
Parhypochthonius sp.				+
Passalozetes bidactylus (Coggi)		+	+	
Pergalumna nervosa (Berlese)	+	+	+	+
Phauloppia lucorum (C. L. Koch)				+
Phthiracarus sp.	+	*	*	*
Quadroppia quadricarinata (Michael)	*	*	o	+
Rhysotritia duplicata (Grandjean)		+		*
Scheloribates laevigatus (C. L. Koch)	+	+	+	*
S. latipes (C. L. Koch)	+	*	*	*
Suctobelba sp.	o	⊛	⊛	o
Tectocepheus velatus (Michael)	⊛	⊛	⊛	⊛
Trhypochthonius tectorum (Berlese)		*	*	
Trichoribates novus (Sellnick)			+	
T. trimaculatus (C. L. Koch)	+	+	+	
Tropacarus carinatus (C. L. Koch)		+		+
Zygoribatula exilis (Nicolet)			+	+
Number of taxa	31	50	41	44

Explanation: Abundance (A) in thousand · $1 m^{-2}$ x/sensu WILLMANN (1931)
⊛ – $A > 10$
o – $5 < A \leq 10$
* – $1 < A \leq 5$
+ – $A \leq 1$

3.4. Density of some populations of Oribatida

In all investigated plots *Tectocepheus velatus* predominated among oribatid mites (Tab. 7). We found this species, as well as *Eremaeus oblongus, Licneremaeus licnophorus* and *Oribatula tibialis*, in relatively low abundance in plot 1, and in distinctly higher density in other polluted plots and in the control. Some mites (*Suctobelba* sp., the species of the family Brachychthoniidae and *Quadroppia quadricarinata*) achieved, in contrast, highest density in polluted plots, compared to the control. These results were statistically significant (Tab. 2). The densities of other

Table 7: The abundance (*A* – mean value in thousand · $1m^{-2}$), dominance (*D*) and constancy (*C*) indices of some taxa of Oribatida in soil areas covered with dead needles, in Scots pine forest polluted by the nitrogen fertilizer factory at Włocławek.

Name of taxon	Plot 1			Plot 2			Plot 3			Control		
	A	*D*	*C*	*A*	*D*	*C*	*A*	*D*	*C*	*A*	*D*	*C*
Adoristes ovatus	1,3	2,9	*68*	1,8	2,3	*80*	0,8	0,9	*48*	2,9	3,6	*80*
Brachychthoniidae	7,3	16,3	*70*	1,2	1,5	*58*	2,7	2,9	*55*	3,0	3,7	*58*
Chamobates schuetzi	0,2	0,4	*33*	0,2	0,3	*20*	0,1	0,1	*8*	0,4	0,5	*35*
Eremaeus oblongus	2,2	4,9	*38*	10,8	13,6	*93*	2,2	2,3	*48*	5,8	7,2	*88*
Licneremaeus licnophorus	0,6	1,3	*23*	2,8	3,5	*53*	16,5	17,6	*73*	3,5	4,3	*40*
Metabelba pulverosa	1,0	2,2	*48*	1,4	1,8	*75*	5,0	5,3	*93*	1,1	1,4	*45*
Oppiella neerlandica	0,9	2,0	*35*	1,4	1,8	*43*	2,8	3,0	*60*	0,4	0,5	*25*
O. nova	0,2	0,4	*13*	0,3	0,4	*33*	0,8	0,8	*50*	1,8	2,2	*43*
Oribatula tibialis	0,2	0,4	*13*	3,0	3,8	*85*	1,8	1,9	*73*	3,9	4,8	*78*
Quadroppia quadricarinata	2,3	5,1	*63*	2,7	3,4	*78*	5,9	6,3	*98*	0,4	0,5	*30*
Scheloribates laevigatus	0,9	2,0	*33*	0,3	0,4	*15*	0,1	0,1	*10*	1,9	2,3	*78*
S. latipes	0,1	0,2	*3*	4,5	5,7	*80*	1,6	1,7	*63*	1,3	1,6	*68*
Suctobelba sp.	7,5	16,7	*98*	10,7	13,5	*100*	14,7	15,7	*100*	5,4	6,6	*90*
Tectocepheus velatus	16,4	36,6	*98*	28,1	35,3	*98*	31,4	33,5	*100*	33,4	41,1	*100*

species were similar both in polluted plots and the control or were too low to analyze.

Tectocepheus velatus was abundant in all investigated plots, but in polluted plots 1 and 2, its density fluctuated greatly between spring and autumn (Tab. 3), probably under the influence of air pollution. In plots 1 and 2, the density in the autumn was respectively 5.8 and 2.1 times higher than in spring, whereas in polluted plot 3 and in the control it was similar or nearly similar in both seasons. Seasonal fluctuation in density was observed also in *Eremaeus oblongus* and *Oribatula tibialis*.

3.5. Species diversity of Gamasida

In total, 42 taxa of Gamasida were found (Tab. 8). Most of them occurred in the control plot, and the fewest lived in plot 1, situated nearest to the pollution source. In polluted plots 2 and 3, the number of taxa was slightly higher than in plot 1, but was distinctly lower than in the control.

Only 11 species were recorded from all investigated plots, 13 species were collected exclusively from the control plot, and 3 exclusively from most polluted plot 1.

3.6. Density of some populations of Gamasida

Among gamasid mites *Veigaia nemorensis* predominated in all polluted plots, whereas *Zercon triangularis* was most dominant in the control (Tab. 9). Relatively abundant were *Eviphis ostrinus, Pergamasus miselllus, Pergamasus* 1 and *Amblyseius obtusus*.

Zercon triangularis achieved the highest density in the control plot, being less abundant in polluted plots. In plot 1, situated nearest to the pollution source, the density was 1/3 that in the control, and in plots 2 and 3, situated further from this source, this species was rare. These results were statistically significant (Tab. 2).

Eviphis ostrinus, Amblyseius obtusus and *Pergamasus* 1 were more abundant in most polluted plot 1 than in the control, whereas *Veigaia nemorensis* was more abundant in plots 2 and 3 than in the control.

4. Discussion

Nitrogen pollution can be considered as an uncontrolled nitrogen fertilization of Scots pine forest. The influence of nitrogen fertilizers on soil animals is usually considered to be a short-term effect of decreased

Table 8

Taxa of Gamasida in soil areas covered with dead needles, in Scots pine forest polluted by the nitrogen fertilizer factory at Włocławek.

Name of taxon	Plot 1	Plot 2	Plot 3	Control
Amblyseius obtusus (C. L. Koch)	*	+	+	+
Anthoseius rhenanus (Oudemans)				+
A. verrucosus Wainstein	+			
Arctoseius cetratus (Sellnick)				+
Asca aphidioides (L.)		+	+	+
Celaenopsis badius C. L. Koch		+		+
Cyrtolaelaps chiropterae Karg			+	
Dendrolaelaps foveolatus (Leitner)				+
Eviphis ostrinus (C. L. Koch)	*	*	+	+
Holoparasitus excipuliger (Berlese)			+	+
Hypoaspis aculeifer (Canestrini)	+	+	+	+
H. austriaca (Sellnick)				+
H. praesternalis Willmann	+	+	*	+
H. vacua (Michael)				+
Lasioseius sp.				+
Leioseius bicolor (Berlese)				+
Pachylaelaps furcifer Oudemans			+	+
Parasitus kraepelini (Berlese)	+			
P. spiniger Trägårdh				+
Parazercon radiatus Trägårdh		+		
Pergamasus crassipes (L.)		+	+	+
P. lapponicus Trägårdh	+			+
P. mediocris Berlese	+			+
P. misellus Berlese	*	*	+	*
P. quisquiliarum (G. et Can.)				+
P. runciger Berlese	+	+	*	+
P. septentrionalis (Oudemans)	+			
P. tectegynellus Athias-Henriot	+	+	+	+
Pergamasus 1	*	*	*	+
Prozercon kochi Sellnick		+		+
Rhodacarellus silesiacus Willmann				+
Rhodacarus coronatus Berlese		+		
Trachytes aegrota (C. L. Koch)		*	+	
Trichouropoda ovalis (C. L. Koch)		+	+	
Uropoda minima Kramer	+	+	+	
Uropoda 1				+
Veigaia cerva (Kramer)	+	+	+	+

Name of taxon	Plot 1	Plot 2	Plot 3	Control
V. exiqua (Berlese)				+
V. kochi (Trägårdh)		+	+	+
V. nemorensis (C. L. Koch)	○	⊛	⊛	○
Zercon cf. *carpathicus* Sellnick				+
Z. triangularis C. L. Koch	*	+	+	⊛
Number of taxa	17	21	20	33

Explanation: Abundance (A) in thousand · $1\,m^{-2}$
⊛ – $A > 2{,}0$
○ – $1{,}0 < A \leq 2{,}0$
* – $0{,}5 < A \leq 1{,}0$
+ – $A \leq 0{,}5$

abundance, and a long-term effect of gradually increasing abundance (HUHTA et al. 1967, LOHM et al. 1977). In the region of Włocławek, the nitrogen pollutants penetrate constantly into the soil, when it is free of snow cover, and therefore these two effects of nitrogen compounds on soil mites overlap. The harmful influence of nitrogen compounds on soil animals is usually explained by the toxic effect of ammonia and so-called "salt-effect", resulting from the increased osmotic potential of soil water: it depends on the concentration of nitrogen compounds in the soil.

In this research a high concentration of nitrogen pollution reduced the abundance of mites and the species diversity of Oribatida, which is consistent with the results of STAINER (1990). In plot 1, situated nearest to the pollution source, the concentration of pollution in the soil was high, and the abundance of mites was only 1/2 that in the control. The pollution mainly reduced the Oribatida, which were dominant in these soils, and also Actinedida, which were second most abundant. The Gamasida, as a group, seemed to be tolerant to air pollution; it occupied all investigated plots in similar densities, except plot 1, where the abundance was slightly lower.

However, in most polluted plot 1 the Gamasida was reduced in species, probably by the air pollution, more than Oribatida. In plot 1, the species diversity of Oribatida was reduced to 70% of that in control, but the species diversity of Gamasida was reduced to 51%. Small concentrations of air pollutants in plots 2 and 3, situated further from the pollution source, increased the species diversity of Oribatida, but decreased the species diversity of Gamasida, compared to the control plot. Thus the bioindicative value of Gamasida was well observed on the species level, but not in the total abundance of this group.

Table 9: The abundance (*A* – mean value in thousand · $1m^{-2}$), dominance (*D*) and constancy (*C*) indices of some species of Gamasida in soil areas covered with dead needles, in Scots pine forest polluted by the nitrogen fertilizer factory at Włocławek.

Name of taxon	Plot 1			Plot 2			Plot 3			Control		
	A	*D*	*C*	*A*	*D*	*C*	*A*	*D*	*C*	*A*	*D*	*C*
Amblyseius obtusus	0,8	11,5	*23*	0,1	1,3	*8*	0,1	1,3	*8*	0,1	1,1	*5*
Asca aphidioides				0,1	1,3	*5*	0,1	1,3	*3*	0,1	1,1	*5*
Eviphis ostrinus	1,0	14,4	*43*	0,6	7,5	*73*	0,3	4,0	*35*	0,1	1,1	*13*
Hypoaspis aculeifer	0,1	1,4	*5*	0,1	1,3	*15*	0,2	2,7	*23*	0,1	1,1	*8*
H. praesternalis	0,1	1,4	*5*	0,1	1,3	*5*	1,0	13,4	*48*	0,1	1,1	*5*
Pergamasus crassipes				0,1	1,3	*18*	0,1	1,3	*15*	0,2	2,2	*25*
P. misellus	0,8	11,5	*38*	1,0	12,5	*100*	0,1	1,3	*8*	0,9	10,1	*55*
P. runciger	0,3	4,3	*33*	0,5	6,3	*83*	0,7	9,4	*73*	0,3	3,4	*35*
P. tectegynellus	0,2	2,9	*13*	0,2	2,5	*25*	0,4	5,4	*43*	0,4	4,5	*25*
Pergamasus 1	0,8	11,5	*38*	0,8	10,0	*43*	0,6	8,1	*78*	0,3	3,4	*18*
Trachytes aegrota				0,8	10,0	*43*	0,1	1,3	*15*			
Uropoda minima	0,1	1,4	*5*	0,1	1,3	*25*	0,4	5,4	*43*			
Veigaia cerva	0,2	2,9	*23*	0,3	3,8	*45*	0,2	2,7	*18*	0,1	1,1	*8*
V. nemorensis	1,1	15,8	*80*	2,3	28,8	*100*	2,6	34,9	*90*	1,8	20,1	*65*
Zercon triangularis	0,8	11,5	*43*	0,1	1,3	*18*	0,1	1,3	*13*	2,4	26,8	*75*

We found some oribatid species (*Tectocepheus velatus, Eremaeus oblongus, Licneremaeus licnophorus* and *Oribatula tibialis*) sensitive to a high concentration of air pollution, what was suggested by their relatively low abundance in plot 1, and distinctly higher densities in other polluted plots and in the control. Some mites (*Suctobelba* sp., the species of the family Brachychthoniidae and *Quadroppia quadricarinata*) tolerated air pollution, and achieved higher densities in polluted plots than in the control.

Tectocepheus velatus is known as an important component of mite associations in forest soil, but it shows a high tolerance to both forest and open areas (RAJSKI 1968, SENICZAK 1978, WEIGMANN & KRATZ 1981). Generally, this species tolerates air pollution, achieving in polluted soils a relatively high density (PORZNER & WEIGMANN 1992, SENICZAK et al. 1993).

In the region of Włocławek *T. velatus* was sensitive to a high concentration of air pollution which is suggested by its relatively low density in most polluted plot 1, and distinctly higher abundances in other plots. Sensitive to air pollution were also *Eremaeus oblongus* and *Oribatula tibialis*. The former species was classified in Switzerland by STAINER (1990) as being sensitive to NO_2 and SO_2 pollution.

Several gamasid species (*Eviphis ostrinus, Amblyseius obtusus* and *Pergamasus* 1) tolerated air pollution; this is suggested by their higher densities in polluted plots than in the control. *Zercon triangularis* was generally sensitive to air pollution, but it is difficult to explain why this species occupied to most polluted plot 1 in a relatively large number, and was rare in less polluted plots 2 and 3, situated further from the pollution source. *Veigaia nemorensis* was, in contrast, sensitive to a high concentration of air pollution, but tolerated small concentrations of these pollutants in plots 2 and 3.

A great seasonal fluctuation in density of mites was observed in polluted plots. This was probably caused by the nitrogen pollution, since it was not observed in the control. The low density of mites in the spring probably resulted from a great mortality of mites in winter. We explain this interesting phenomenon by the harmful effect of toxic pollutants on soil mites. When these pollutants are joined into a soil sorption complex, their physical properties are changed, and like ammonia they lose their toxicity (ODUM 1982). The thick snow layer which covers the soil in winter dries gradually the soil, and the capacity of the soil sorption complex diminishes in the upper soils horizons. In this situation some nitrogen compounds, which are stored in the soil during growing season, are released from this complex, and after attaining higher concentrations under the snow cover, they are lethal to mites. A high concentration of

some nitrogen compounds, like ammonia, is toxic to mites (FRANZ 1953, MOURSI 1962, WARREN 1962).

During the growing season the mites found in polluted plots good development conditions, as is suggested by 2 - 3 times higher abundance in the autumn than in the spring. However, in plot 1, situated nearest to the pollution source, this seasonal increase was distinctly lower than in polluted plots 2 and 3, which probably indicates more soil degradation. This observation is supported by a relatively low species diversity of Oribatida and Gamasida in plot 1.

The fluctuation in density of soil mites is undoubtedly harmful for forest ecosystems. The mites are known as very important components of soil fauna in the process of organic matter decomposition (DUNGER 1970, PUCHALSKI & PRUSINKIEWICZ 1975). All changes in their density therefore disturb this process and can create problems with the provision of plants with mineral compounds necessary for growth.

A great fluctuation in density of mites in polluted plots can be interpreted as a persistent resistance of mites, as a component of biocenoses, to all changes in forest ecosystems caused by nitrogen pollutants. In the region of Włocławek, the mites were reduced in the spring, but they reproduced intensely in the growing season, in some polluted plots exceeding the level of the control. In non-polluted forest soil, seasonal fluctuation in density of mites was not observed (RAJSKI 1961, SENICZAK 1978).

A persistent resistance of mites to all changes in forest ecosystems caused by nitrogen pollutants was also realized by the replacement of some sensitive species by other mites which tolerate air pollution. This phenomenon was well observed both in Oribatida and Gamasida. Some oribatid species sensitive to air pollution (mainly *Tectocepheus velatus, Eremaeus oblongus* and *Oribatula tibialis*) were replaced by others (mainly *Suctobelba* sp., the species of the family Brachychthoniidae and *Quadroppia quadricarinata*) which tolerated these pollutants. In gamasid mite associations *Zercon triangularis* was replaced, in polluted plots, by *Eviphis ostrinus, Amblyseius obtusus, Pergamasus* 1 and other species with tolerated air pollution.

The Gamasida occupied in relatively high numbers both the polluted plots and the control, especially in the autumn, and seems to tolerate, as a group, the air pollution. A high participation of predatory Gamasida in mite associations in polluted plots is undoubtedly useful for forest ecosystems. These mites eat some saprophagous mites, like Oribatida, and to a certain degree, they soften the fluctuation in saprophage density in polluted forests, and thereby regulate the rate of decay of organic matter.

5. Conclusions

1. Small concentrations of nitrogen pollution stimulated the abundance of soil mites and increased the species diversity of Oribatida, but decreased the species diversity of Gamasida; a high concentration of pollutants was harmful to these mites.

2. Among soil mites there were species sensitive to air pollution (*Tectocepheus velatus, Eremaeus oblongus, Oribatula tibialis*) and taxa which tolerated these pollutants (*Suctobelba* sp., the species of the family Brachychthoniidae and *Quadropia quadricarinata*).

3. A seasonal fluctuation in density of soil mites was observed in polluted plots, but not control, between spring and autumn; this probably resulted from the great mortality of mites in winter, and the stimulating influence of some pollutants on the development of mites during the growing season.

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